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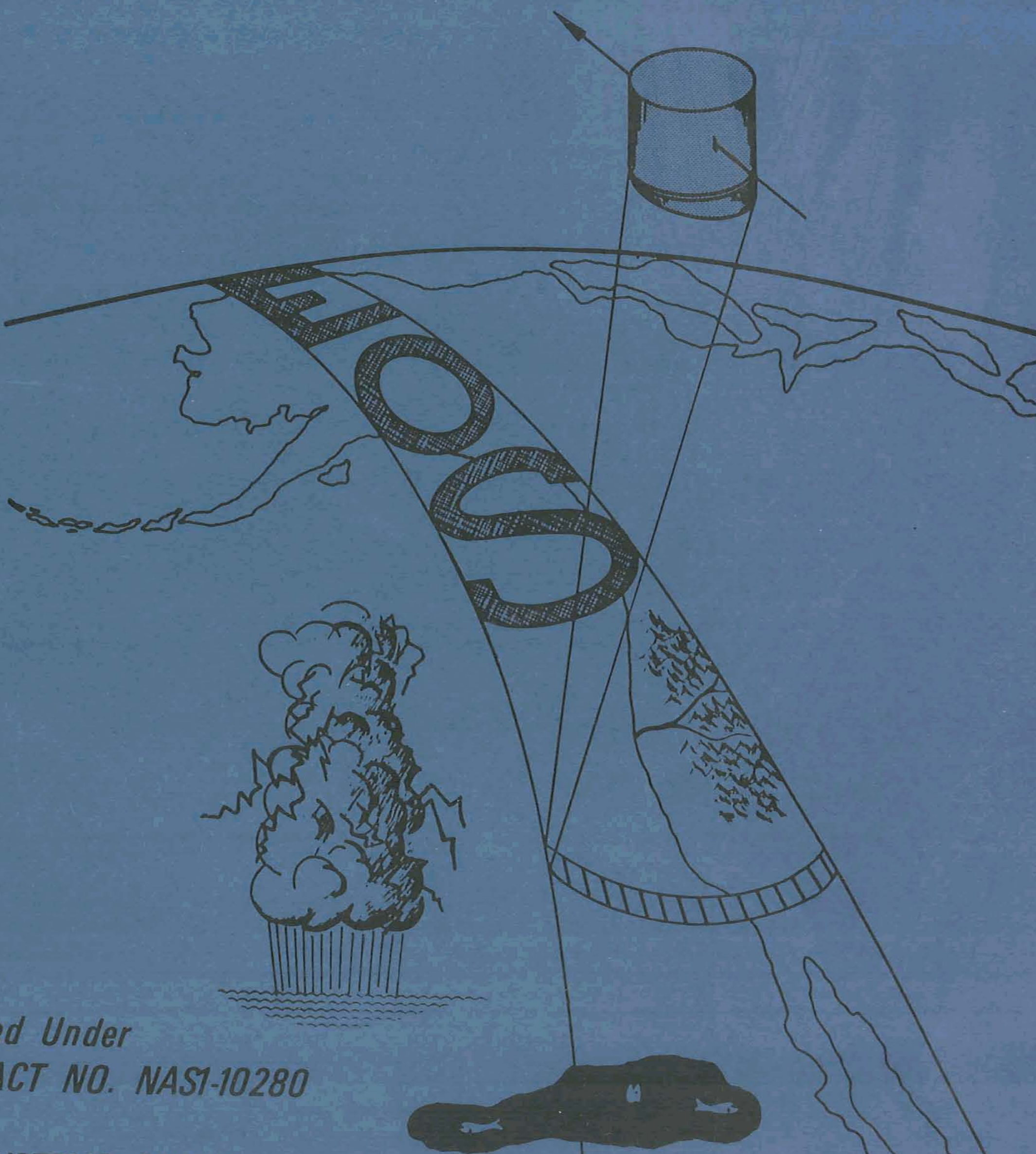
Summary

COASTAL-ZONE REQUIREMENTS FOR EOS A/B

Final Report



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For

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
Langley Research Center
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REPRO VELLUM

NASA CR-111818
Summary

FINAL REPORT

COASTAL-ZONE OCEANOGRAPHIC REQUIREMENTS FOR EARTH OBSERVATORY SATELLITES A & B

4 February 1971

Technical Contract Monitor

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ABSTRACT

This study identified information requirements for effective management and conservation of our Coastal Zones, and determined what significant problem-oriented data could best be provided by space platforms.

Information needs were classified into the major priorities of Pollution, Fisheries, Hazards to Shipping and Coastlines, and Geography/Hydrology/Cartography. Experiment requirements and associated missions were independently developed for each of these, and for a multi-priority mission.

Optimum and minimum sensor payload groupings and corresponding requirements were developed for each priority. The merit of performing the selected missions was also established.

The results of the study show that there is a significant need for Pollution and Fisheries dedicated payloads. For coastal Geography/Hydrology/Cartography, there are requirements that EOS A/B* could fulfill and which will not be provided by other spacecraft in the 1974-76 time frame. A mission dedicated to the Hazards priority would not provide significant additional information beyond that currently planned by other spacecraft programs.

*Throughout the report EOS A/B is referred to as ERTS E/F.

INTRODUCTION

A study examining the potential utility of spacecraft in meeting critical needs for data in the coastal zone was undertaken by TRW Systems Group under NASA Contract NAS1-10280. A comprehensive analysis of coastal zone oceanographic data needs was performed, and spacecraft missions were recommended that would contribute most significantly to four major priority issue categories; coastal Pollution, Fisheries, Hazards to shipping and coastlines, and coastal Geography, Hydrology and Cartography.

The coastal zones, for the purposes of this study, are defined to be those regions influenced by the transition between land and the sea. That is, the breadth of the coastal zone is determined by:

1) All land and water inland to the limit of tidal action, including inland seas, such as the Great Lakes, and

2) Seaward to the limit of land derived influence.

Specifically the study objectives were

- definition of coastal zone information needs
- determination of information needs that can be provided by EOS A/B
- definition of space experiment requirements
- establishment of sensor concepts and orbital requirements
- definition of missions and their relevancy to national priority issues

The principal aim of the study was to determine what, if any relevant problem-oriented information can be best provided by a spacecraft dedicated to the coastal zones in the 1974 to 1976 time frame. Thus, the study was not directed toward determining what types of classical oceanographic data can be acquired by a space platform but toward ascertaining the problems confronting the coastal regions and how best can a satellite be used toward solving these problems.

STUDY APPROACH

The study commenced with the central theme of coastal zone management and conservation, to which all types of oceanographic data will be applied. This requires information in four broad categories:

1. Baseline description of the coastal zone
2. Continuously updated summary of human activity
3. Mutual interaction of man and the ocean
4. Plans and desires of man relative to the coastline.

Problem areas can be categorized such as mentioned above, but they are highly iterative and overlap in countless details. This is demonstrated by the results of the study.

The approach taken in developing information requirements and respective missions was to independently consider each priority. A capsule summary of the study approach is given below and are illustrated in Figure 1.

- General information needs for the high-priority coastal issues (Pollution, Fisheries, Hazards to navigation and coastlines, and Geography, Hydrology and Cartography) were identified.

- The general all-inclusive national needs were then broken down into more specific implied information needs. Major information needs -- critical to the national priorities -- were distinguished from minor or noncritical specific information needs.

- Physical phenomena which require investigation to meet the specific information needs were next identified.

- Properties of the phenomena of interest which are amenible to measurement were tabulated in matrix form. These "environmental measurables" were enumerated without regard to the manner in which the measurement is most appropriately made, be it from shipboard, ground station, aircraft or satellite.

- Environmental measurables which merit consideration for their potential for sensing from a space platform were identified. Certain of these "remote space observables" related only indirectly to the phenomena of interest, and were appropriate designated. These remote space observables were arranged in matrices according to the appropriate general type of electromagnetic sensing device.

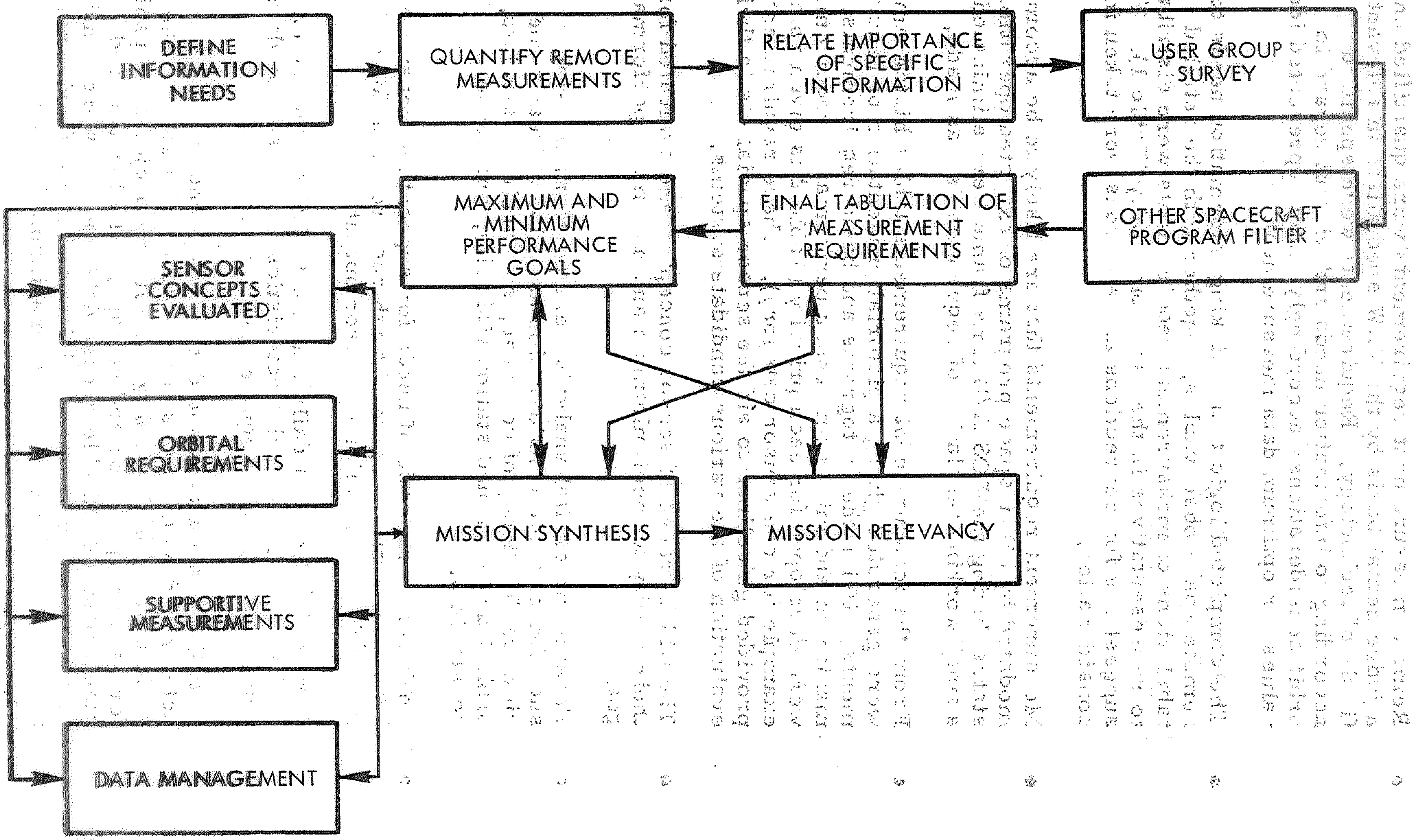

Figure 1. Study Approach Schematic

- Remote measurement requirements were quantified on a judgemental basis by the TRW specialists in relevant fields of technology. Requirements were specified according to information needs and without regard to orbit considerations; accordingly, they represented ideal values for optimum data measurements.

- The completed logic trains linking information needs to remote space observables, together with the detailed tabulations of measurement requirements were distributed to representatives in the user community (Table 1). Their suggestions for corrections and additions were taken into consideration.

- Measurement requirements that are likely to be accommodated by other space programs of expected operational status during the EOS A/B time frame were eliminated and a final working tabulation of requirements was made.

- From the measurement requirements tables histograms were generated giving a pictorial presentation of requirements. Using the histograms and basic requirements, maximum and minimum sensor performance requirements were developed for each priority (Table 2 is given as an example for one sensor category). These requirements provided guidelines to aid the sensor specialists in their evaluation of the various candidate systems.

- The widest range of sensor concepts were evaluated for their ability to meet minimum and maximum performance goals.

- Parametric orbital analysis were performed taking such factors into consideration as: global areas to be viewed, frequency of coverage, sun-angle constraints, orbital drag, ground station visibility, and sensor constraints.

- Analyses were made of needs for supporting measurements, both in the sense of ground truth requirements for calibration and interpretation of sensor output.

- Data rates and total daily data load were calculated on the basis of mission characteristics (e.g., sensor data outputs, coverage, requirements, etc.).

- Data-link bandwidths and data storage requirements were determined on the basis of a review of the state of the art in data handling technology, including projected capabilities for data compression and storage. The location and capabilities of suitable ground data stations were considered in conjunction with on-board data storage and orbit parameters, which would dictate maximum data handling capacity.

Table 1. User Survey Personnel

NAME OF CONTACT	AGENCY REPRESENTED	PRIORITY PRIMARY CONTRIBUTION	PRIORITY SECONDARY CONTRIBUTION
WILLIAM S. DAVIS	FEDERAL WATER QUALITY ADMINISTRATION	POLLUTION	HAZARDS
MEL GREENWOOD (FOR HARVEY BULLIS)	NATIONAL MARINE FISHERIES SERVICE (NMFS)	FISHERIES	POLLUTION
G. CARPER TEWINKEL (INSTEAD OF CAPT. L. W. SWANSON)	COAST AND GEODETIC SURVEY	CARTOGRAPHY	HAZARDS
HENRY YOTKO (INSTEAD OF JOHN W. SHERMAN)	NAVOCEANO	GENERAL	
TAIVO LAEVASTU	FLEET NUMERICAL WEATHER CENTRAL (U.S. NAVY)	FISHERIES	HAZARDS
ROBERT DOW	MARINE DEPARTMENT OF SEA AND SHORE FISHERIES	FISHERIES	
WHEELER J. NORTH	CALIFORNIA INSTITUTE OF TECHNOLOGY	POLLUTION	
EDWARD EHLERS (INSTEAD OF ROBERT WALKER)	CALIFORNIA DEPARTMENT OF NAVIGATION AND OCEAN DEVELOPMENT	CARTOGRAPHY	
L. H. CLOYD	CALIFORNIA DEPARTMENT OF FISH AND GAME	FISHERIES	
ED GREENHOOD	CALIFORNIA DEPARTMENT OF FISH AND GAME	FISHERIES	
ROBERT LEWIS	CALIFORNIA WATER QUALITY BOARD	POLLUTION	
GORDON BROADHEAD AND FRANK ALVERSON	LIVING MARINE RESOURCES, INC.	FISHERIES	HAZARDS
RESPONSES ALSO SOLICITED FROM:			
RICHARD MADRUGA	(FISHING VESSEL CAPTAIN)	FISHERIES	
ADMIRAL LESLIE GHERES	(MANAGER OF NATIONAL MARINE TERMINAL – AN OPERATOR OF TWELVE TUNA VESSELS)	FISHERIES	
HAROLD CARY	(VICE-PRESIDENT OF A SEAFOOD PROCESSING AND MARKETING COMPANY, WESTGATE, CALIFORNIA)	FISHERIES	

Table 2. Ultimate Sensor Design Goals

VISIBLE AND NEAR IR SPECTROMETRY/IMAGING

	SPECTRAL RANGE (μ)	SPECTRAL BANDWIDTH (μ)	GROUND RESOLUTION (FEET)	F.O.V. (MILES)	SENSITIVITY* (W/M^2 ST/μ)	OBSERVATION FREQUENCY (DAYS)
GEOGRAPHY						
OCEAN COLOR						
MAXIMUM PERFORMANCE GOALS	0.4 - 1.2	0.02	100	50	0.1 - 1.0	1
MINIMUM PERFORMANCE GOALS	0.4 - 0.7	0.05	100	50	0.1 - 1.0	14
GLITTER						
MAXIMUM PERFORMANCE GOALS	0.4 - 0.7	BD	50	GLITTER PATTERN	1.0 - 10.0	1
MINIMUM PERFORMANCE GOALS	0.4 - 0.7	BD	50	GLITTER PATTERN	1.0 - 10.0	7
FISHERIES						
OCEAN COLOR						
MAXIMUM PERFORMANCE GOALS	0.4 - 1.2	0.01	25	50	0.01 - 0.1	1
MINIMUM PERFORMANCE GOALS	0.4 - 0.7	0.05	100	50	0.1 - 1.0	7
GLITTER SENSOR						
MAXIMUM PERFORMANCE GOALS	0.4 - 0.7	BD	50	100	1.0 - 10.0	1
MINIMUM PERFORMANCE GOALS	0.4 - 17.0	BD	100+	50	1.0 - 10.0	7
HAZARDS						
OCEAN COLOR						
MAXIMUM PERFORMANCE GOALS	0.4 - 1.2	0.05	50	100	0.1 - 1.0	1
MINIMUM PERFORMANCE GOALS	0.4 - 0.7	BD	100	100	1.0 - 10.0	1
GLITTER ANALYSIS						
MAXIMUM PERFORMANCE GOALS	0.4 - 0.7	BD	100	ENTIRE GLITTER PATTERN	1.0 - 10.0	1
MINIMUM PERFORMANCE GOALS	0.4 - 0.7	BD	300	100	1.0 - 10.0	1
POLLUTION						
OCEAN COLOR						
MAXIMUM PERFORMANCE GOALS	0.4 - 1.2	0.01	100	50	0.01 - 0.1	1
MINIMUM PERFORMANCE GOALS	0.4 - 0.7	0.03	300	50	0.01 - 1.0	7
GLITTER						
MAXIMUM PERFORMANCE GOALS	0.4 - 17.0	BD	100	ENTIRE GLITTER PATTERN	1.0 - 10.0	1
MINIMUM PERFORMANCE GOALS	0.4 - 0.7	BD	100	50	1.0 - 10.0	7

*SUBJECT TO ORBIT/COVERAGE ANALYSIS

- Minimum and optimum sensor groupings were established within reasonable bounds for total payload weight, power requirements, and data rates for each priority.
- Sensor characteristics for a range of altitudes were defined in terms of size, weight, power, and performance requirements for each selected sensor.
- Optimum and minimum payloads, and corresponding orbital characteristics were established for each priority.
- The relevancy of performing each mission was also assessed.

RESULTS

Study results show there is a significant need for EOS payloads dedicated to Coastal Pollution and Fisheries. For the Geography/Hydrology/Cartography priority, there are requirements that the EOS program could fulfill and which will not be provided by other spacecraft in the 1974-76 time frame. A mission dedicated to the Hazards priority would not provide significant additional information beyond that currently planned by other spacecraft programs, such as Nimbus.

The results of the study are documented in such a manner that if new information needs arise they could be translated into new sensor requirements, or the capability of new sensors can be evaluated.

The recommended optimum and minimum payload grouping for each priority and a multi-priority optimum grouping is contained in Tables 3, 4, and 5, respectively. Table 6 contains the recommended orbital characteristics for these groupings.

The recommended sensor groupings contain only one existing sensor, the sun glitter RBV sensor. All other recommended sensors require development. This is due to coastal oceanic phenomena requiring:

- Very fine spectral resolution
- Very high instrument sensitivity
- Fine spatial resolution

The type of recommended orbits are near polar sun-synchronous which have a very slow eastward translation, and require 40 days for complete global coverage. An orbital altitude of 300 nmi is also recommended.

Table 3. Summary of Optimum Sensor Groupings (300 NMI Altitude)

NATIONAL PRIORITY	GLITTER CAMERA	VISIBLE/NEAR-IR IMAGING	INFRARED IMAGING/ RADIOMETRY	PASSIVE MICROWAVE	SIDE LOOKING RADAR	TOTAL SENSOR PAYLOAD SIZE, WEIGHT, POWER
POLLUTION	RBV FRAMING CAMERA WITH POINTING MIRROR $\Delta\mu = 0.58$ TO 0.66 $\Delta S = 175'$/PIXEL 100 X 100 NM FRAME 100: 1 DYNAMIC RANGE	MULTI-SPECTRAL IMAGING SENSOR $\mu = 0.4$ TO 0.9 $\Delta\mu = 0.2$ AND 0.01 $\Delta S = 75'$(BB), 300'(NB) $S = 100$ NM SENSITIVITY: 0.1 TO 1 $W/M^2 - ST - \mu$	7.5", 32 DETECTOR CONSCAN $\mu = 10$ TO 12.5 $\Delta S = 300'$ $S = 200$ NM $\Delta T = 0.5$, $NE\Delta T = 0.1°K$		SIDE LOOKING RADAR IMAGER $f = 10$ GHz $\Delta f = 13.3$ MHz $\Delta S = 300$ FT $S = 100$ NM	7.9 FT^3 + 30' x 8" x 1.5" UNFURLED ANTENNA 487 LBS, 600 W
FISHERIES		SAME AS ABOVE	SAME AS ABOVE	MICROWAVE RADIOMETER $f = 19$ GHz, $\Delta f = 300$ MHz $\Delta S = 10$ NM $S = 200$ NM $\Delta T = 1.5$, $NE\Delta T = 0.7°K$	SAME AS ABOVE	6.9 FT^3 + FIVE ANTENNAS 30' x 8" x 1.5" UNFURLED 6' x 12', 3.7' x 6.3', 4' x 5', 2.1' x 2.7' 770 LBS, 700W
HAZARDS		MULTI-SPECTRAL IMAGING SENSOR $\mu = 0.4$ TO 0.7 $\Delta\mu = 0.1$ $\Delta S = 100$ FT $S = 100$ NM SENSITIVITY: 0.1 TO 1 $W/M^2 - ST - \mu$	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE	6.4 FT^3 + FIVE ANTENNAS 30' x 8" x 1.5" UNFURLED 6' x 12', 3.7' x 6.3', 4' x 5', 2.1' x 2.7' 698 LBS, 650W
GEOGRAPHY		MULTI-SPECTRAL IMAGING SENSOR $\mu = 0.4$ TO 0.9 $\Delta\mu = 0.1$ $\Delta S = 100'$ $S = 100$ NM SENSITIVITY: 0.1 TO 1 $W/M^2 - ST - \mu$			SAME AS ABOVE	3.9 FT^3 + 30' x 8" x 1.5" UNFURLED ANTENNA 331 LBS, 450W

LEGEND:
- f = FREQUENCY
- Δf = BANDWIDTH
- μ = SPECTRAL RANGE, MICRONS
- $\Delta\mu$ = SPECTRAL RESOLUTION, MICRONS
- ΔS = SPATIAL RESOLUTION (PICTURE ELEMENT)
- S = SWATH WIDTH, NMI
- $NE\Delta T$ = MINIMUM DETECTABLE TEMPERATURE DIFFERENCE
- ΔT = ABSOLUTE SENSOR TEMPERATURE CALIBRATION
- BB = BROADBAND, NB NARROWBAND

Table 4. Summary of Minimum Sensor Groupings (300 NMI Altitude)

NATIONAL PRIORITY	GLITTER CAMERA	VISIBLE/NEAR-IR IMAGING	INFRARED IMAGING/ RADIOMETRY	PASSIVE MICROWAVE	SIDE LOOKING RADAR	TOTAL SENSOR PAYLOAD SIZE, WEIGHT, POWER
POLLUTION		MULTI-SPECTRAL IMAGING SENSOR μ = 0.4 TO 0.9 $\Delta\mu$ = 0.2 AND 0.01 ΔS = 75'(BB), 300'(NB) S = 100 NM SENSITIVITY: 0.1 TO 1 $W/M^2 - ST - \mu$	7.5", 32 DETECTOR CONSCAN μ = 10 TO 12.5 ΔS = 300' S = 200 NM ΔT = 0.5, $NE\Delta T = 0.1^{\circ}K$			$5.65\ FT^3$ 230 LBS, 250W
FISHERIES		SAME AS ABOVE	SAME AS ABOVE			$5.65\ FT^3$ 225 LBS, 250W
HAZARDS		MULTI-SPECTRAL IMAGING SENSOR μ = 0.4 TO 0.7 $\Delta\mu$ = 0.1 ΔS = 100 FT S = 100 NM SENSITIVITY: 0.1 TO 1 $W/M^2 - ST - \mu$		MICROWAVE RADIO-METER f = 19 GHz, Δf = 300 MHz ΔS = 10 NM S = 200 NM ΔT = 1.5, $NE\Delta T = 0.7^{\circ}K$		$2.3\ FT^3$ + FOUR ANTENNAS 6' x 12', 3.1' x 6.3', 4' x 5', 2.1' x 2.7' 470 LBS, 240W
GEOGRAPHY		MULTI-SPECTRAL IMAGING SENSOR μ = 0.4 TO 0.9 $\Delta\mu$ = 0.1 ΔS = 100' S = 100 NM SENSITIVITY: 0.1 TO 1 $W/M^2 - ST - \mu$				$2.7\ FT^3$ 156 LBS, 150W

LEGEND:
- f = FREQUENCY
- Δf = BANDWIDTH
- μ = SPECTRAL RANGE, MICRONS
- $\Delta\mu$ = SPECTRAL RESOLUTION, MICRONS
- ΔS = SPATIAL RESOLUTION (PICTURE ELEMENT)
- S = SWATH WIDTH, NMI
- $NE\Delta T$ = MINIMUM DETECTABLE TEMPERATURE DIFFERENCE
- ΔT = ABSOLUTE SENSOR TEMPERATURE CALIBRATION
- BB = BROADBAND, NB NARROWBAND

Table 5. Multi-Priority Payload

	SPECTRAL RANGE OR FREQUENCY	SPECTRAL RESOLUTION OR BANDWIDTH	SPATIAL RESOLUTION (FT/PIXEL)	SENSITIVITY (WATT/M^2/ST/μ)	NEΔT RELATIVE TEMPERATURE SENSITIVITY (DEGREE K)	ΔT ABSOLUTE TEMPERATURE ACCURACY (DEGREE K)	NEAREST BEAUFORT NUMBER	SWATH WIDTH (N MI)	FREQUENCY OF COVERAGE (DAYS)	SIZE OR VOLUME	WEIGHT (POUNDS)	POWER (WATTS)
MULTI-SPECTRAL	0.4 TO 0.7μ (30 CHANNELS)	0.01 μ	300' NB CHANNELS	0.25				100		2.75 FT^3	173	141
IMAGING SENSOR	0.7 TO 0.9μ (1 CHANNEL)	0.2μ	75' BB CHANNEL									
GLITTER FRAME CAMERA	.58 TO .66μ	.08μ	175'	100:1 DYNAMIC RANGE				100x100 NMI FRAME		1 FT^3	64	45
THERMAL IR	10 TO 12.5μ	2.5μ	300'		0.1	0.5		200		2.9 FT^3	70	110
SIDE LOOKING RADAR	10 GHz	13.3 MHz	300'					100	1 (ALL)	1.2 FT^3 PLUS 30'x8"x1.5" UNFURLED ANTENNA	180	300
PASSIVE MICROWAVE RADIOMETER SYSTEM	19 GHz	300MHz	10 NMI		0.7	1.5	0-12	200		FOUR ANTENNAS 6'x12',3.1'x6.3' 4'x5',2.1'x2.7'	350	150
DATA COLLECTION SYSTEM	450 MHz 405 MHz							2100		.15 FT^{3}x20" DIA ANTENNA	7	21
TAPE RECORDERS (2)	(30 MINUTE RECORDING, 4 MHz BANDWIDTH)									2 FT^3 EACH	68 EACH	83 EACH
PAYLOAD TOTAL										12 FT^3 PLUS SIX ANTENNAS: 30'x8'x1.5' UNFURLED, 6'x12',3.1'x6.3',4'x5', 2.1'x2.7', 20" DIA. (TOTAL 122 SQ FT.)	980 LBS	935W

Table 6. Selected Orbits

	Q (ORBITS/DAY)	S (DEGREE/NMI) AT EQUATOR	P (MINUTES)	h (NMI)	i (DEGREE)	Ω_0 (DEGREE)	e	ω
POLLUTION	15 1/40	23.96 1437	95.84	302	97 X 37'	325	0	0
FISHERIES	15 1/40	23.96 1437	95.84	302	97 X 37'	325	0	0
HAZARDS	15 1/40	23.96 1437	95.84	302	97 X 37'	325	0	0
GEOGRAPHY	13 17/18	25.82 1549	103.27	492.6	99 X 30.6'	325.5	0	0
MULTIPLE MISSION	15 1/40	23.96 1437	95.84	302	97 X 37'	325	0	0

The advantage of this type of orbit is that geographical areas can be viewed on a daily basis for periods up to ten days. The duration of daily coverage depends upon the sensor field of view, the size of and the latitude of geographic areas of interest.

The final recommended cyclic frequency for complete equatorial zone coverage requires further investigation. However, with this type of orbit near daily coverage can be provided on a worldwide basis.

Another advantage of this type of orbit is that with a modest amount of velocity increment, daily coverage can be obtained for any desired length of time. Thus, selected geographic areas such as the west coast or any other inflight selected geographic area can be viewed on a daily basis. It is thus recommended that the space platform include in-plane velocity adjust capability for this purpose.

The geographic areas used in establishing the data load are presented in Figure 2. It was assumed that orbits and system sizing will be based on U. S. coastal requirements only. This would still permit substantial support to other countries, but only as development of non-U. S. ground stations and use of the satellite off-duty cycles relative to U. S. coastal waters permitted.

To size the data problem for U. S. coastal zones, including Hawaii and Alaska, we have segmented the coastlines and ranked each area by its relative importance for each of the national coastal zone priority problems. Three levels of importance were used in ranking the various coastal areas:

1) Major area of importance directly affects U. S. interests
2) Less critical area or may only indirectly affect U. S. interests
3) Area of limited concern or importance to U. S.

The results of this work are summarized in Table 7. Coastal regions other than the U. S. are also included in the table since they are of some importance to U. S. interests, particularly for fisheries. The coastline miles shown represent the distance along the shoreline where coverage is desired. The total coastline miles corresponding to each national priority category are presented in Table 7. These results, coupled with the resolution and sensor field of views were used to size the data load, which was found to be comparable to the ERTS A/B data load.

SENSOR CLASS	POLLUTION (DAYS) OBS. FREQ.	POLLUTION (NMI) F.O.V.	FISHERIES (DAYS) OBS. FREQ.	FISHERIES (NMI) F.O.V.	HAZARDS (DAYS) OBS. FREQ.	HAZARDS (NMI) F.O.V.	GEOGRAPHY (DAYS) OBS. FREQ.	GEOGRAPHY (NMI) F.O.V.
VISIBLE AND NEAR SPECTROMETRY/IMAGING	1-7	100-200	1-7	100	1	100	14	100
RADAR SCATTEROMETRY/ IMAGING	1	100	1	100	1	100	7	100
MICROWAVE RADIOMETRY			1	100	1	200		
IR RADIOMETRY	7	200	1-7	200				

Figure 2. Geographic Regions of Interest

Table 7. Total Miles of Coastline Coverage

NATIONAL PRIORITY CATEGORY	NAUTICAL MILES OF COASTLINE			
	PRIORITY RANKING WITHIN CATEGORY			TOTAL
	1	2	3	
POLLUTION	2200	2300	1400	5,900
FISHERIES	6100	7500	12,200	25,800
HAZARDS	7300	3200	11,900	22,400
GEOGRAPHY	3050	1650	1200	5,900